Radiowave Propagation Issues for In-Situ Communications

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Introduction

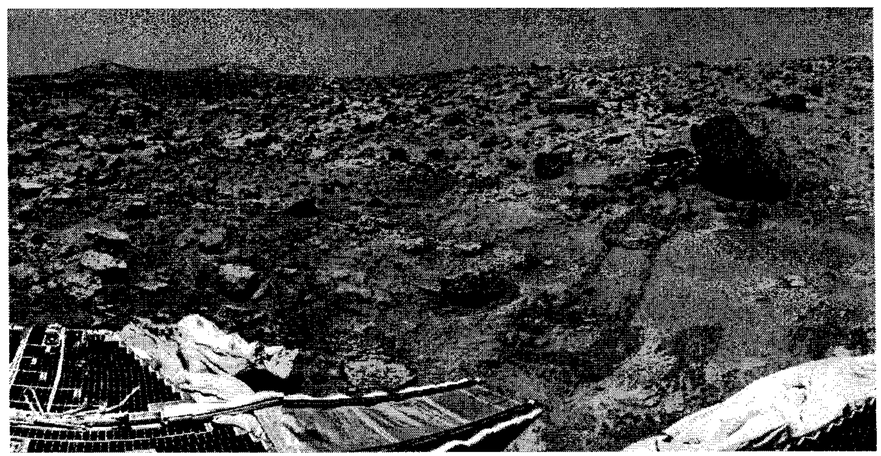
- Preceding presenters have provide an interesting look at the role of in-situ communications for exploration of our solar system in a range of diverse environments
  - Reasonable understanding of radiowave propagation in these diverse space environments is needed for effective design and operations of in-situ communications systems for exploration of our Solar System

- NASA's Cross Enterprise Technology Development Program has funded a research proposal for characterization of radiowave propagation for space exploration; this paper presents the preliminary findings of the work relevant to in-situ communications on two very different planetary environments - arid deserts of Mars and oceans of Europa
  - For three decades, NASA's commercial technology programs have successfully lead the US efforts for characterization of radiowave propagation for effective design of satellite communications systems; the expertise and the knowledge base is being leveraged to support the propagation work in support of in-situ communications

The Propagation Environment on Mars

- As an example, let us consider the propagation environment for the Mars Pathfinder landing site. The photo shows the lander site with a relatively benign line-of-sight propagation channel between the lander and the rover through the clear Martian atmosphere with modest scattering/reflection from the surrounding area
- The In-Situ Communications designer may want to know:
  - How can the line-of-sight range be extended?
  - What are the risks of signal blockage or fades with the rover behind or close to rocks or hidden by the terrain as a function of range?
  - What are the propagation tradeoffs between the use of UHF versus S-band for this application

- In the next few slides we will look at the basics of radiowave propagation to address some of these issues.



Scattering

- Scattering of radiowave signal is generally caused by sharp discontinuities in the medium;
  - It is convenient to define a scattering cross section for each object, defined as the ratio of the total power scattered by the object divided by the power flux density incident on the object
  - For sharp long edges (several wavelengths long) the effective scattering cross section A_s is proportional to the edge length (L) times the wavelength (λ) times a dimensionless constant (K<1) whose magnitude depends on properties of the scattering surface
    - $A_s = = K\lambda L$
  - Everything else being the same, scattering is reduced due to the smaller scattering cross section at higher frequencies

Scattering continued

- When the scattering object is distant from both the transmitter and receiver compared to the dimensions of the scattering object, the scattered power received at the receiver (P_{rs}) is proportional to the transmitted EIRP, the scattering cross section of the object (A_s), the effective aperture of the receiving antenna (A_r), and is inversely proportional to the square of the object-transmitter distance (R_1) and object-receiver distance (R_2).

$$P_{rs}=(EIRP).(A_r).(A_s).(R_1^{-2}.\ R_2^{-2})/(16\ \pi^{2)}$$

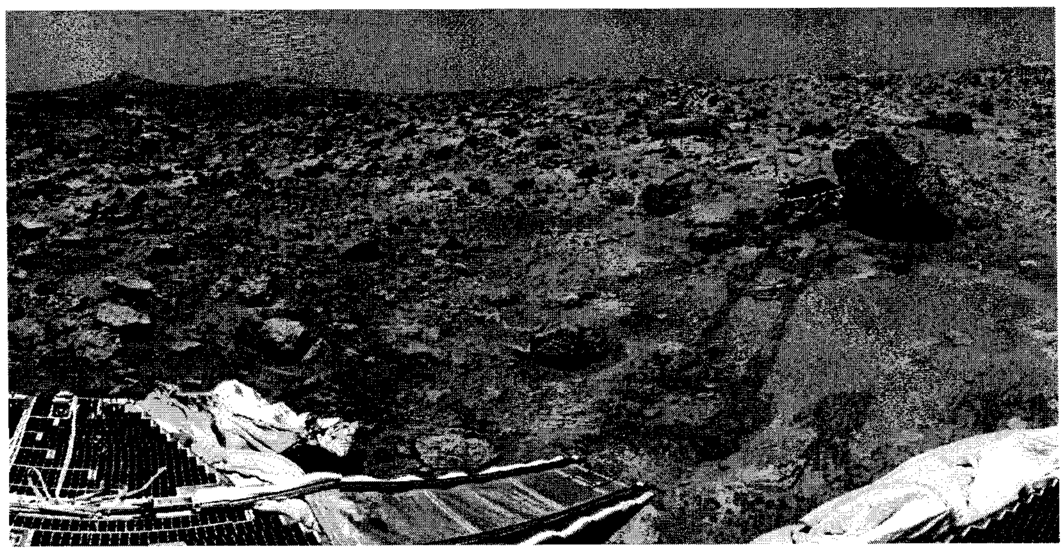
- For the line-of-sight signal, direct power received at the receiver is proportional to the EIRP, the effective aperture of the receiving antenna and inversely proportional to the square of transmitter-receiver range R.

$$P_{rd}=(EIRP).(A_r).(R^{-2)})/(4\ \pi)$$

- When the received scattered signal level is compared to the wanted direct signal, one can conclude:
  - Unwanted scattering is worst when the scattering object is close to the transmitter or the receiver
  - Unwanted scattering is reduced in proportion to frequency due to a smaller scattering cross section

Signal Blockage

- Signal blockage caused by objects or terrain features between the in-situ transmitter and the receiver on Mars can be a real problem unless the theater of operations is limited to a small area in a fairly flat terrain with relatively few large rocks
  - The in-situ telecom system designer would need to rely on robust communication protocols or operational procedures to recover from such link blockage or depend on Mars orbiting relays to reduce blockage problems
  - Positioning the base station on a commanding location will help reduce blockage probability and extend the line of sight range



Frequency tradeoffs for Communications on Mars

- Mars in-situ communications systems currently under considerations envision the use of UHF as the frequency of choice; this has been also true for land mobile communications on Earth although the use of higher frequencies is becoming common for new land mobile communication systems on our planet.
- It would be interesting to make a quick comparison of UHF verses S-band for both Land Mobile and Mars In-Situ Communications.
  - UHF is the frequency of choice for land mobile because of its ability to penetrate foliage, lightly constructed buildings and its ability to provide a link to cars at city street level through scattered power over building roof edges.
  - For Mars in-situ-communications there are no significant differences between UHF and S-band from propagation characteristics; therefore the choice should be decided on non-propagation issues
    - Non propagation issues could include existing of legacy technologies (UHF), larger effective receiver aperture (UHF), suitability to directional links by use of medium gain antennas (S-band) to extend the range.

Summary, The Propagation Environment on Mars

- Did we answer the three questions we wanted to answer on in-situ-communications on Mars?
  - Question: How can the line of sight range be extended?
  - Answer: Place lander on commanding ground or use higher antennas to extend line of sight range; if necessary use directional antennas to extend range

  - Question: What are the risks of signal blockage or fades with the rover behind or close to rocks or hidden by the terrain as a function of range?
  - Answer: Risks are real; use robust communications protocols and robust operation concepts

  - Question What are the propagation tradeoffs between the use of UHF versus S-band for this application
  - Answer: Generally a wash on propagation issues;but from a system perspective:
    - UHF is probably more convenient for short range low rate applications
    - S-band may have an advantage to extend range/data rate by allowing use of medium gain antennas

Propagation Issues for Exploration of Europa Oceans

- Interest in exploring planetary oceans is the rational for looking at radiowave propagation through bodies of water
- On Earth, this subject has been extensively studied for submarine communications
- It is commonly known that most promising frequencies for underwater communications includes:
  - Very long wave; generally not practical for space applications due to the need for very large antennas
  - Use of sound and ultrasound waves- this is probably the best solution; will transmit through ice as well
  - Optical frequencies - only practical in clear water
  - Wire or optical fiber to connect the transmitter and receiver

Conclusions

- We have looked at radiowave propagation issues for in-situ communications for two different space environments:
  - On Arid deserts of Mars
  - Through oceans of Europa
- Proposal just funded by NASA's Cross Enterprise Technology Program will enable us to pay more attention to this important subject
- In the meantime a timely advice to in-situ telecommunications system designers:
  - Please remember that propagation work tries to ESTIMATE AND PREDICT the statistics of the link impairments due to propagation impairments; it cannot GUARNTEE a specific performance- use robust communications protocols or robust operational concepts to deal with variances from predicted performance
  - Most communications systems proposing to use complicated solutions to solve difficult propagation problems have failed; look for a system architecture with a benign propagation environment

Acknowledgements

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